Weaving practices with science content: what the research says about student learning

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Arizona Department of Education

Goals for Today

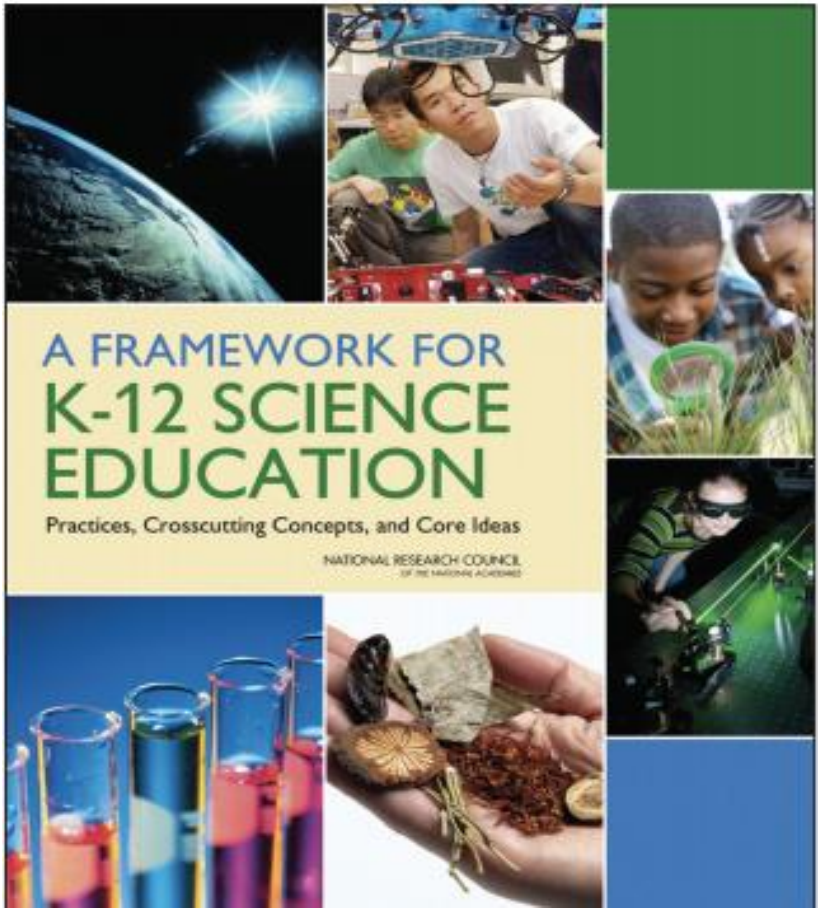
- Understand current research on science education
  - *A Framework for K-12 Science Education*
  - Learning Progressions

- Understand design of Arizona's Science Standard

- Analyze a 4th grade science objective and identify instructional shifts needed for three-dimensional science instruction.

Current Research on K-12 Science Education

The Framework outlines research on science learning that leads to a new vision of teaching.



Download the Framework for K-12 Science Education
http://www.nap.edu/catalog.php?record_id=13165

Structure of the Framework

Contains three dimensions:

- Dimension 1 – Scientific and Engineering Practices
- Dimension 2 – Crosscutting Concepts
- Dimension 3 – Disciplinary Core Ideas

Scientific and Engineering Practices

1. Asking questions and defining problems (pp. 54-56)
2. Developing and using models (pp. 56-59)
3. Planning and carrying out investigations (pp. 59-61)
4. Analyzing and interpreting data (pp. 61-63)
5. Using mathematics and computational thinking (pp. 64-66)
6. Developing explanations and designing solutions (pp. 67-71)
7. Engaging in argument from evidence (pp. 71-74)
8. Obtaining, evaluating, and communicating information (pp. 74- 77)

Connect to AZCCRS Mathematics Connect to AZCCRS ELA/Literacy

2004 Arizona Science Standard	A Framework for K-12 Science Education
Strand 1: Inquiry 1. Observations, Questions, and Hypotheses 2. Scientific Testing (Investigating and Modeling). 3. Analysis, Conclusions, and Refinements 4. Communication: Communicate results of investigations. How do these differ?	Science and Engineering Practices 1. Asking questions and defining problems 2. Developing and Using Models 3. Planning and Carrying Out Investigations 4. Analyzing and Interpreting Data 5. Using Mathematics and Computational Thinking 6. Constructing Explanations and Designing Solutions 7. Engaging in Argument from Evidence 8. Obtaining, Evaluating, and Communicating Information

Comparison Activity: Practices

Review the example learning progression for Planning and Carrying Out Investigations (p.2)

Arizona Strand 1 Concept 2: Scientific Testing (Investigating and Modeling) **Participate in planning and conducting investigations, and recording data.**
PO 1. Demonstrate safe behavior and appropriate procedures (e.g., use and care of technology, materials, organisms) in all science inquiry.
PO 2. Plan a simple investigation that identifies the variables to be controlled.
PO 3. Conduct controlled investigations (e.g., related to erosion, plant life cycles, weather, magnetism) in life, physical, and Earth and space sciences.
PO 4. Measure using appropriate tools (e.g., ruler, scale, balance) and units of measure.
PO 5. Record data in an organized and appropriate format (e.g., t-chart, table, list, written log).

What are key differences between Arizona's Science Standard and the Framework?

Crosscutting Concepts

1. Patterns, similarity, and diversity (pp. 85-86)
2. Cause and effect (pp. 87-89)
3. Scale, proportion and quantity (pp. 89-91)
4. Systems and system models (pp. 91-94)
5. Energy and matter (pp. 94-96)
6. Structure and function (pp. 96-98)
7. Stability and change (pp. 98-101)

Provides conceptual framework to connect understandings into a coherent and scientifically-based view of the world

2004 Arizona Science Standard	A Framework for K-12 Science Education
Only mentioned on page viii of Introduction 1. Systems, Order, and Organization 2. Evidence, Models, and Explanation 3. Constancy, Change, and Measurement 4. Evolution and Equilibrium 5. Form and Function	Cross-cutting Concepts 1. Patterns 2. Cause and effect 3. Structure and Function 4. Energy and Matter 5. Systems and System Models 6. Scale, Proportion and Quantity 7. Stability and Change How do these differ?

Comparison Activity: Crosscutting Concepts

Review the example learning progression for Energy and Matter (p.6)

What are key differences between Arizona's Science Standard and the Framework?

Disciplinary Core Ideas (DCIs)

Focus on the most important aspects of science content across four domains:

- physical sciences
- life sciences
- Earth and space sciences
- engineering, technology and applications of science

Disciplinary Core Ideas

Must meet at least two of the four criteria:

- broad importance across multiple disciplines or a key organizing concept of a single discipline
- key tool for understanding/investigating more complex ideas and solving problems
- connect to societal or personal concerns/interests that require scientific or technological knowledge
- teachable/learnable over multiple grades at increasing levels of depth and sophistication (learning progressions)

2004 Arizona Science Standard	A Framework for K-12 Science Education
Strand 4: Life Sciences 1. Living systems – molecules to organisms 2. Heredity – Inheritance and variation of traits 3. Organisms and Environments/Ecosystems 4. Diversity, adaptation, evolution	Core Ideas in Life Sciences 1. From Molecules to Organisms: Structures and Processes 2. Ecosystems: Interactions, Energy, and Dynamics 3. Heredity: Inheritance and Variation of Traits 4. Biological Evolution: Unity and Diversity

2004 Arizona Science Standard	A Framework for K-12 Science Education
Strand 5: Physical Sciences 1. Properties of matter and chemical reactions 2. Motion and Forces 3. Energy 4. Interactions of energy and matter	Core Ideas in Physical Sciences 1. Matter and Its Interactions 2. Motion and Stability: Forces and Interactions 3. Energy 4. Waves and Their Applications in Technologies for Information Transfer

2004 Arizona Science Standard	A Framework for K-12 Science Education
Strand 6: Earth/Space Sciences 1. Earth's materials 2. Earth's systems and cycles 3. Earth in the Solar system 4. Origin and evolution of the Universe Also see Strand 3: Science in Personal and Social Perspectives 1. Changes in Environments	Core Ideas in Earth and Space Sciences 1. Earth's Place in the Universe 2. Earth's Systems 3. Earth and Human Activity

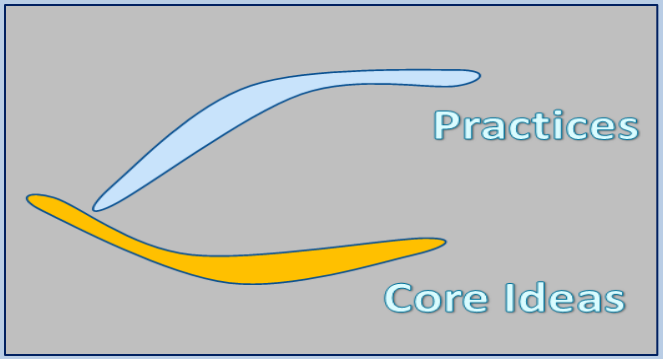
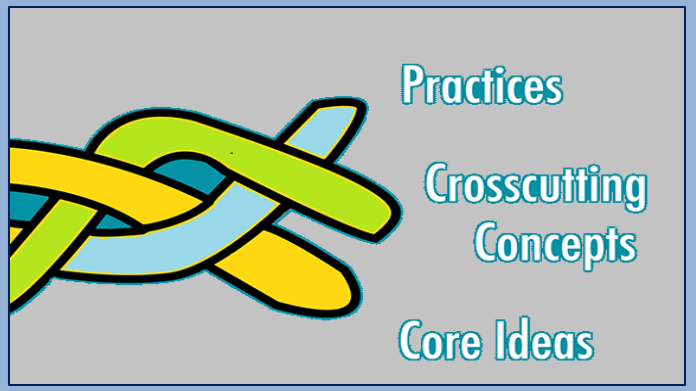
Comparison Activity:
Disciplinary Core Ideas

Review the example learning progression for Energy (p.9)

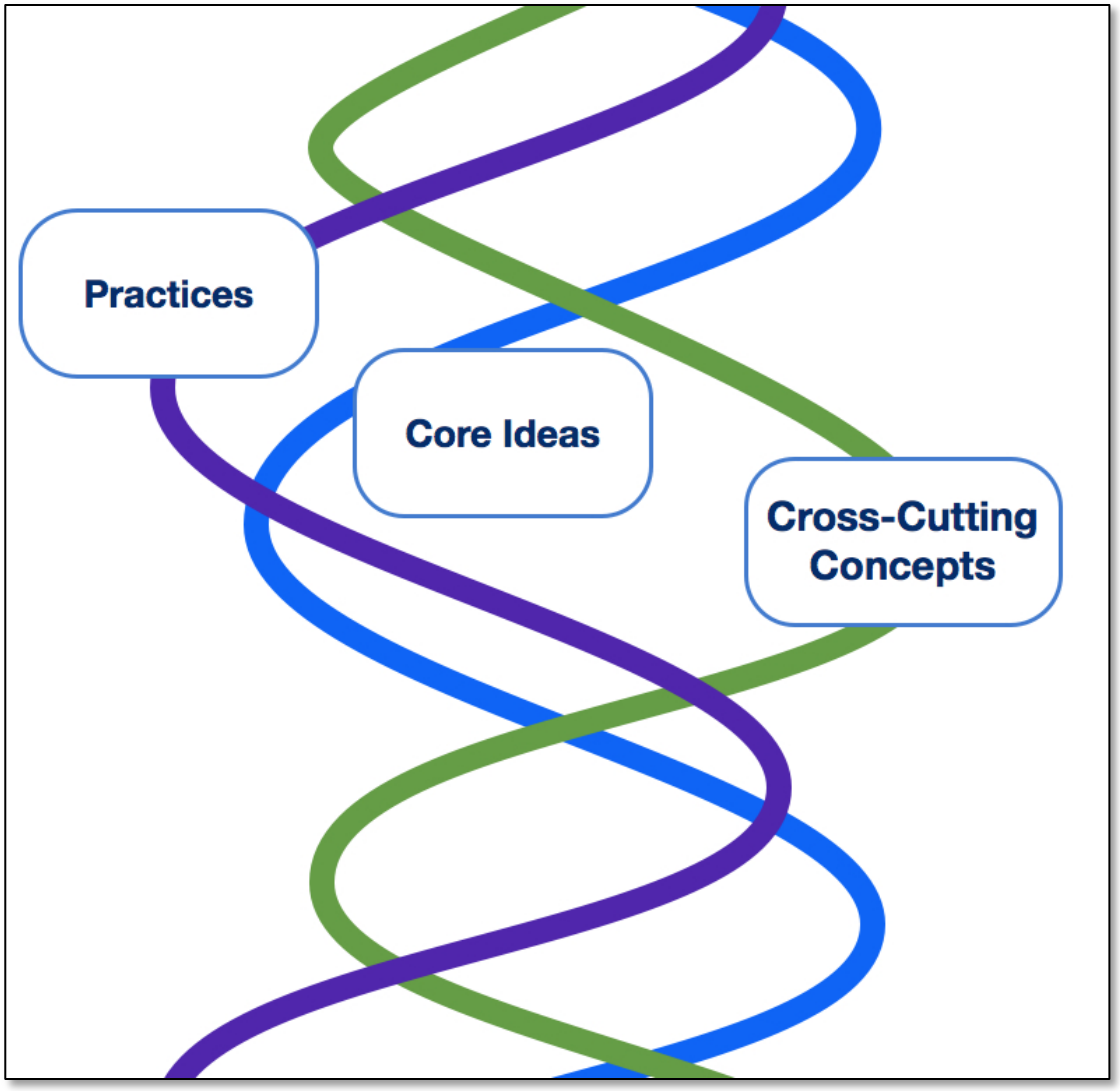
Strand 5, Concept 3: Energy and Magnetism **Investigate different forms of energy.**
PO 1. Demonstrate that electricity flowing in circuits can produce light, heat, sound, and magnetic effects.
PO 2. Construct series and parallel electric circuits.
PO 3. Explain the purpose of conductors and insulators in various practical applications.
PO 4. Investigate the characteristics of magnets (e.g., opposite poles attract, like poles repel, the force between two magnet poles depends on the distance between them).
PO 5. State cause and effect relationships between magnets and circuitry.

What are key differences between Arizona's Science Standard and the Framework?

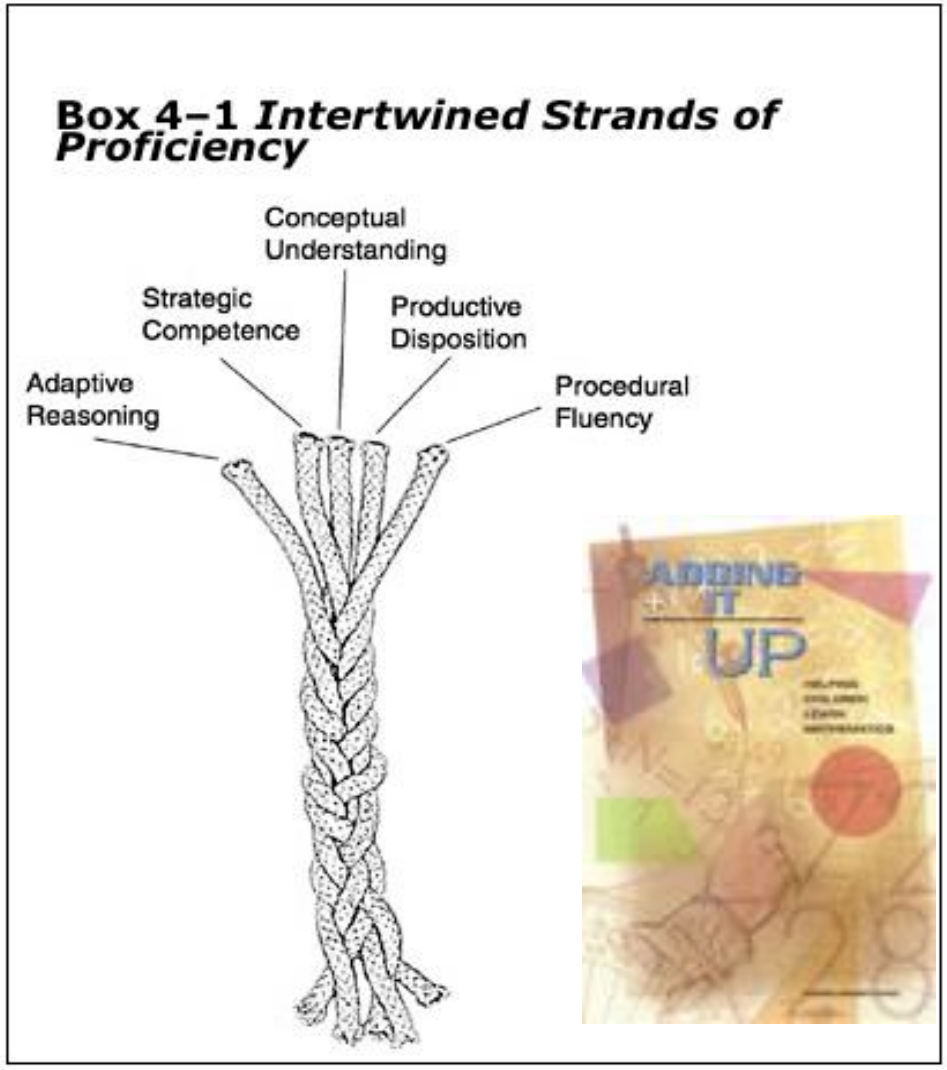
Making a Case for 3-Dimensional Science Instruction

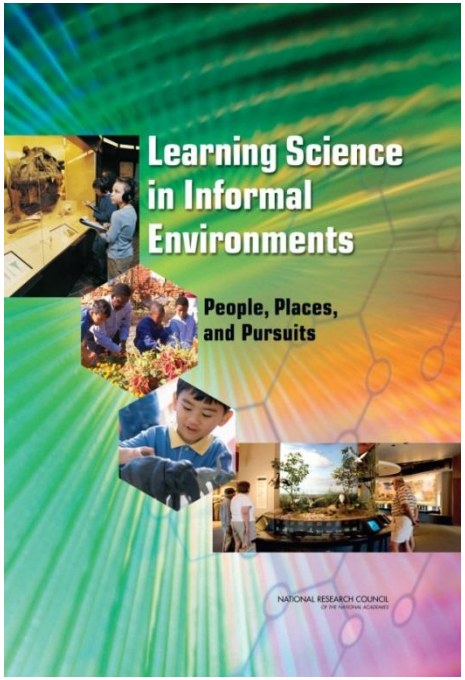
2004 Arizona Science Standard	A Framework for K-12 Science Education
Organization: • Designed in 6 Strands • Strands 1-3 (practices/application) intended to be taught in conjunction with Strands 4, 5, or 6 (content). • Each strand assessed (via AIMS) separately, so often taught separately. 	Organization: • Focused around three dimensions of learning. • Research supports explicitly connecting all three dimensions. • Research supports assessments at the intersection of the three dimensions. 

Three Dimensions Intertwined

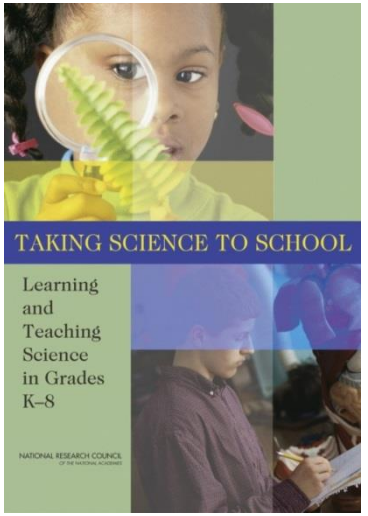


How do we know this approach works?





6 strands – incorporates affective domain



4 strands

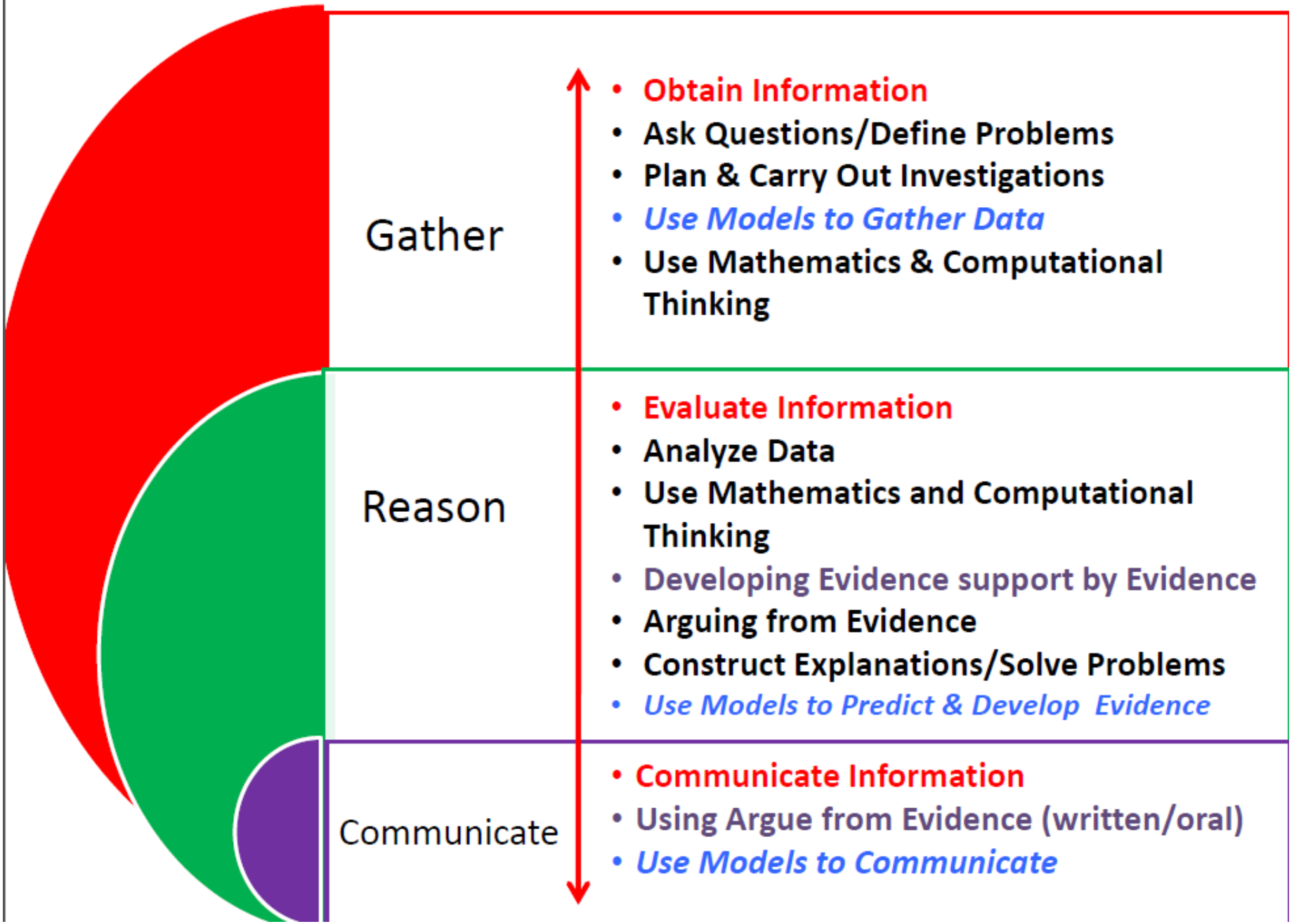
Science and Engineering Practices

- more than teaching strategies
- how scientific knowledge is acquired
- students need to demonstrate achievement in their use and application

Vision for Science Instruction

Engage all students in developing the knowledge and skills to:

1. **Gather** – Obtain and evaluate information
2. **Reason** – Construct explanations of phenomena and use evidence to develop arguments
3. *Communicate* – Communicate explanations using evidence and Core ideas to support scientific arguments


Gather
Obtain Information
Ask Questions/Define Problems
Plan & Carry Out Investigations
Use Models to Gather Data
Use Mathematics & Computational Thinking
Reason
Evaluate Information
Analyze Data
Use Mathematics and Computational Thinking
Developing Evidence support by Evidence
Arguing from Evidence
Construct Explanations/Solve Problems
Use Models to Predict & Develop Evidence
Communicate
Communicate Information
Using Argue from Evidence (written/oral)
Use Models to Communicate

Conceptual Shifts of Vision

1. K-12 science education should reflect the interconnected nature of science as it is practiced and experienced in the real world.

2004 Arizona Science Standard	A Framework for K-12 Science Education
• Content standards rarely make real-world connections. • Nature of Science is stand-alone concept • Scientific practices focus on inquiry/experimentation and don't explicitly connect to content.	• Reflects the interconnected Nature of Science as it is practiced and experienced in the real world.
• Engineering design and technological applications of science is stand-alone concept (Strand 3, Concept 2)	• Science and engineering are integrated from K–12.

Conceptual Shifts of Vision

1. K-12 science education should reflect the interconnected nature of science as it is practiced and experienced in the real world.

2. Science concepts build coherently from K-12.

Learning Progressions
Develop Conceptual Understanding

	K-2	3-5	6-8	9-12
PS1.A Structure of matter	Objects can be built up from smaller parts. Matter exists as different substances that have observable different properties. Different properties are suited to different purposes.	Because matter exists as particles that are too small to see, matter is always conserved even if it seems to disappear. Measurements of a variety of observable properties can be used to identify particular substances.	The fact that matter is composed of atoms and molecules can be used to explain the properties of substances, diversity of materials, states of matter, phase changes, and conservation of matter.	The sub-atomic structural model and interactions between electric charges at the atomic scale can be used to explain the structure and interactions of matter, including chemical reactions. Repeating patterns of the periodic table reflect patterns of outer electrons. A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart.

2004 Arizona Science Standard	A Framework for K-12 Science Education
• Basic concepts present K-12, but individual topics don't always build during each grade band (example: electricity/magnetism only in grades K, 4, HS; waves only in grades 3, HS) • Spiraling of content is based on 15-20 year old research on how students learn science and important content.	• Science concepts build coherently from K–12, based on current research on student learning progressions in science and what content is required to build conceptual understanding.

Conceptual Shifts of Vision

1. K-12 science education should reflect the interconnected nature of science as it is practiced and experienced in the real world.

2. Science concepts build coherently from K-12.

3. Focus on deeper understanding of content as well as application of content.

2004 Arizona Science Standard	A Framework for K-12 Science Education
• Many objectives focused on learning "facts" of science and not building conceptual understanding. • Application in Strands 1, 2, 3 and separated from the content strands.	• Focus on deeper understanding of content as well as application of content.
• Designed for high school graduation. • Not all students graduate with instruction in all standards.	• Designed to prepare students for college, career, and citizenship. • Intent is for <u>all</u> students to learn <u>all</u> progressions.
• Adopted in 2004 and do not align to AZCCRS.	• Practices connect to the AZCCRS.

Shift from Arizona's Science Standard to 3-Dimensional Instruction

Student Expectations
4th Grade Energy

Arizona Science Standard

SC04-S5C3-01.
Demonstrate that electricity flowing in circuits can produce light, heat, sound, and magnetic effects.

3-Dimensional Objective

Conduct investigations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

What do students need to know and be able to do?

Bundling objectives for understanding

- Performance objectives taught in isolation lead to a disjointed view of science.
- Instruction should lead to understanding the larger core idea.
- Coherent instructional materials and instruction should focus on Disciplinary Core Idea(s) rather than discrete pieces that are never tied together.
- Instruction should connect the 3 Dimensions to reflect how science is practiced and experienced in the real world.

Shifting to 3-Dimensional Instruction

1. Review the learning progression for a disciplinary core idea.

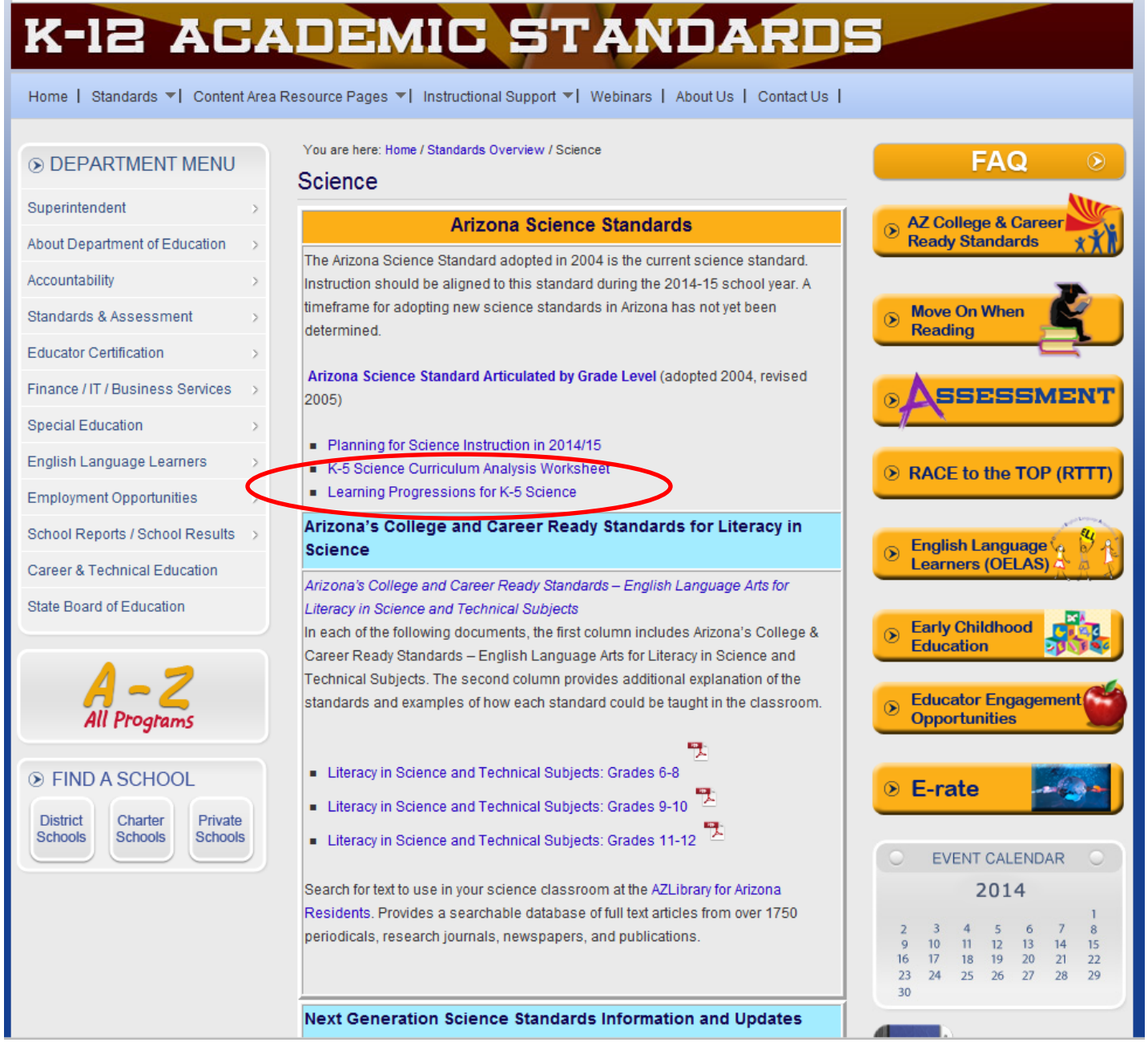
2. Examine the content of the core idea at your grade level (Framework and AZ Science Standard)
   - What instructional changes will need to be made to implement the shift to 3-Dimensional instruction?
   - What changes to materials, teacher professional development, etc. will need to be implemented to teach this progression?

Guidelines for developing K-5 Science Curriculum Analysis Worksheet

Current research on science education emphasizes the importance of integrating the learning progressions from all three dimensions included in *A Framework for K-12 Science Education.* This Curriculum Analysis Worksheet is a tool that can be used to change your current instructional practices and deepen student learning.

1.	Identify a science concept or concepts within Arizona's Science standard from Strands 4, 5 or 6. Fill in the title of the science concept at the top of the worksheet.
2.	Identify the conceptual understandings within Strands1-3 (Practices and Crosscutting concepts) and Strands 4-6 (Content Learning Progressions).
3.	a. Identify the current objectives from the Arizona Science Standard from Strands 1, 2 and 3 that align with the learning progressions you have identified from the Learning Progressions for K-5 document. b. Examine your current science curriculum to identify ways you can start to reach the vision of *A Framework for K-12 Science Education* while you currently teach objectives from your grade level Arizona Science Standards.
4.	a. Identify the current objectives from the Arizona Science Standard from Strands 4, 5, and 6 that align with the learning progressions you have identified from the Learning Progressions for K-5 document. b. Examine your current science curriculum to identify ways you can start to reach the vision of *A Framework for K-12 Science Education* while you currently teach your grade level objectives from the Arizona Science Standard.
5.	a. Identify the current Arizona Science standard crosscutting concept or concepts that align with the learning progressions you have identified from the Learning Progressions for K-5 document. b. Examine your current science curriculum to identify ways you can start to reach the vision of *A Framework for K-12 Science Education* while you currently teach your grade level objectives from the Arizona Science Standard.

Resources



http://www.azed.gov/standards-practices/academic-standards/science/

NEXT GENERATION SCIENCE STANDARDS
For States, By States

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The Next Generation Science Standards

Printer-friendly version

Thank you for your feedback on the second draft of the Next Generation Science Standards. The standards are now being revised based on your feedback, and will be available on this webpage once they are completed in March of 2013.

- NGSS Structure
- NGSS Second Draft Front Matter
- Appendices to the Second Draft:
  - A. Conceptual Shifts
  - B. Responses to May Public Feedback
  - C. College and Career Readiness
  - D. All Standards, All Students
  - E. Disciplinary Core Idea Progressions
  - F. Science and Engineering Practices / Matrix
  - G. Crosscutting Concepts / Matrix
  - H. Nature of Science
  - I. Engineering, Technology, and Applications of Science
  - J. Model Course Mapping in Middle and High School
  - K. Connections to CCSS-Mathematics
- Why Standards Matter
- Public Attitudes Toward Science Standards
- Video: Why NGSS?

All of the materials released for the second public draft review period were working drafts and were removed from the website during the revision period.

The NGSS are composed of the three dimensions from the NRC Framework. Click on the links to the left to learn more about the standards.

http://www.nextgenscience.org/next-generation-science-standards

Thank You!

K-12 Academic Standards Section
High Academic Standards for Students Division
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